Journal of Natural Disaster Science, Volume 17, *Number* 2, 1995, *pp.*1-12

THE GREAT HANSHIN-AWAJI EARTHQUAKE DISASTER: DAMAGE, SOCIAL RESPONSE, AND RECOVERY

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(Received 11 July, 1995 and in revised form March 20, 1996)

ABSTRACT

This January 17 earthquake was a killer earthquake that struck one of the world's largest port cities. As of June 30, the toll from the earthquake in the Kansai region was 5,502 dead, 2 missing, and 39,708 injured. More than half of the dead were over 60 years old. Inner city problems such as densely populated urban areas with old wooden houses and very narrow streets intensified the severity of damage. More than 500,000 houses and buildings were partially or completely destroyed. The slow start of the search and rescue operations and lack of emergency management increased the human and property damage. The redundancy of the water supply systems and quick recovery of electric power contributed to the stabilization of the regional society in spite of the massive damage. The maximum number of evacuees at shelters was 316,678 on January 23; about 20,000 remained on June 30. About 60,000 temporary housing units were planned and some were completed as early as the second week after the earthquake. During these first two weeks, the number of residents rescued in Kobe City was 1,888 but those surviving only 733. The total number of fires in Kobe was 176, and the area burned about 70ha. In terms of economic damage, the loss of property was ¥11.6 trillion, 2.5% of the Japanese GDP (¥466 trillion in 1994).

1. INTRODUCTION

The Hyogo-ken Nanbu earthquake occurred at 5:46 am. on January 17, 1995. Except for the great 1923 Kanto earthquake which destroyed large areas of Tokyo and Yokohama and killed 143,000 people, no other such disastrous event has occurred in 20th century Japan. As of March 28, the toll from the earthquake in Kobe and adjacent cities and towns was 5,504 dead and missing, and 39,708 injured.

The hypocenter of the earthquake was located about 20km southwest of downtown Kobe City between the northeast tip of Awaji Island and the mainland (Fig.1). It was focused about 13.2km under the northeast tip of Awaji Island and had a Japan Meteorological Agency magnitude of 7.2.

The Great Hanshin-Awaji Earthquake Disaster has taught us many lessons. It exposed the wretched fragility of highly advanced urban infrastructures such as the artificially made Port Island and Rokko Island with modern port facilities, the network systems of railroads, subways and highways, and other lifeline systems that extended in a narrow zone along the coast. Historically, typhoons and heavy rainfall have been the cause of natural disasters in the Kobe area. For example, in 1896, 1903, 1905, 1910, 1932, 1935, 1938, 1945, 1961, and 1967, Kobe suffered sediment disasters due to heavy rainfall. In 1933, large scale debris flows that accompanied flooding killed 616 people. Therefore, for the residents and local governments sediment flow has been a main source of disaster in this area. No emergency management plans had taken into account the possibility of a major earthquake close to this densely populated urban area.

KEY WORDS: Great Hanshin Awaji earthquake disaster, Liquefaction, Fire, Lifelines, Emergency management, PTSD, Preparedness, Vulnerability

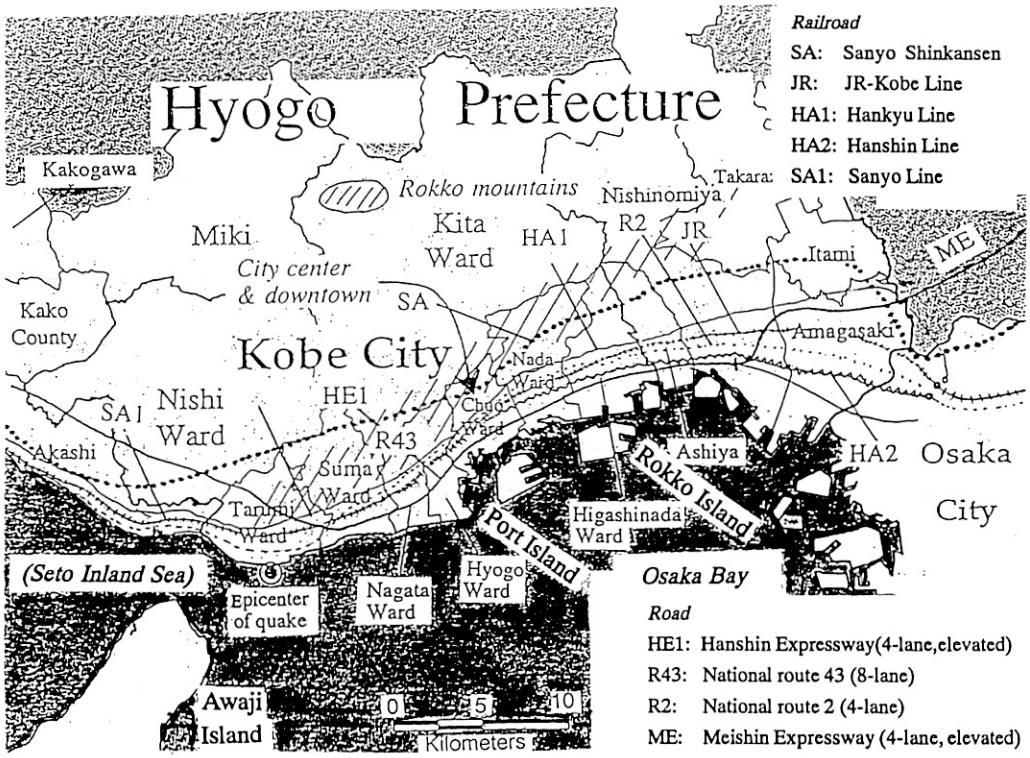

Fig. 1. Map of the damaged areas.

Table 1. Damage to human life and property.

Human damage		Facility and construction damage	
dead	5,502	educational institutions	766
missing	2	roads	9,403
severely wounded	1,819	bridges	321
slighly wounded	25,029	river levees	427
under inspection	14,679	landslides	367
House damage		**Lifeline damage**	
collapsed	100,282		(households)
half ruined	108,402	water supply	1,277,851
minor damage	185,756	city gas	856,835
		telephone	286,231
Building damage			
Public bldgs.	549	Fires	294
Others	3,126		

Table 1 shows the human and property damage done by this earthquake.

2. HUMAN DAMAGE

The earthquake and the fires that followed it caused 5,504 fatalities. More than 39,708 people were injured. More than half of the dead were over 60 years old, most of whom lived in old wooden houses in the densely populated areas of the inner city of Kobe. Traditional style Japanese houses have very heavy tile roofs to resist the strong winds that accompany typhoons. The Kobe area had not experienced a major earthquake for more than one thousand years, and the local governments and residents in this area had no experience of an earthquake with an epicenter close to Kobe (in this one the distance between the epicenter and city center was only 20km).

In Kobe, fire department workers rescued 1,888 people over a period of two weeks, but only 733 of them survived. On the first day, there were 486 survivors, on the second 129, and on the third 89, 96% of the total rescued (Fig.2). These three days are called the "golden seventy-two hours" for rescue, and this disaster proved it correct. Neighbors' help and cooperation are very important just after an earthquake. In this event, many university students living in dormitories and other young people took active parts in rescue operations. Because of the very high land costs in large Japanese cities, young families live on the outskirts of cities. This has been the trend through the end of bubble economy of early 1990s. In the inner city, older people who have lived for more than twenty to thirty years in cheap rented houses can not move elsewhere because of expensive house and commuting costs. Therefore, vulnerability to natural disasters has increased year by year.

In Kobe City fire fighters number about 2,000 but only 291 were on duty. Policemen on night duty numbered about 300. Therefore, only about 600 officers were immediately available at the time of the disaster. The emergency number, 119, received 6,922 calls on January 17th, 3,483 on the 18th and 2,306 on 19th at the information control center in Kobe. The daily average number of emergency calls in 1994 was 436 and for fires and accidents 150 (Fig.3). Due to the earthquake, many poles bearing electric and telephone lines were broken and, the building and facilities of NTT (Nippon Telephone and Telegram) were partially damaged. Switchboard capacity

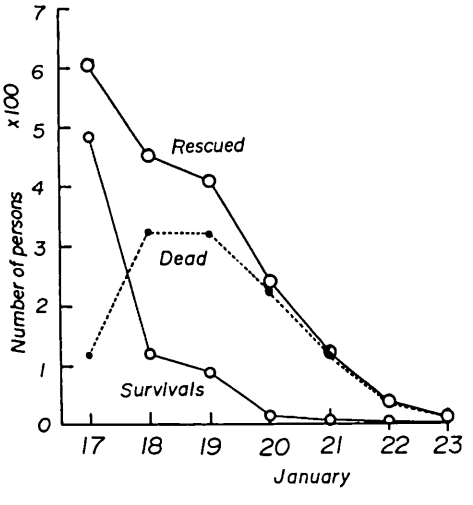

Fig. 2. Search & rescue operation statistics for Kobe City.

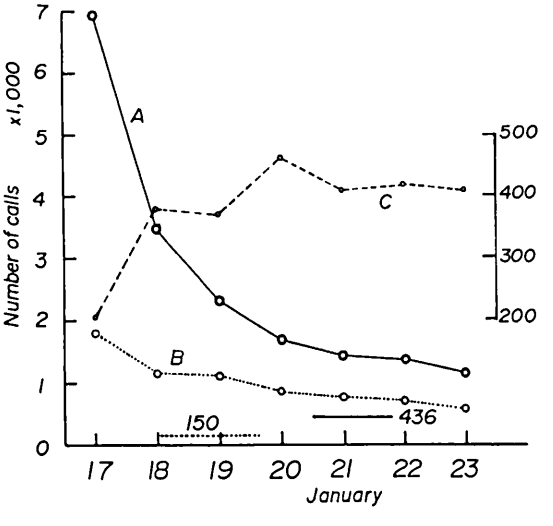

Fig. 3. Emergency calls.

also was not sufficient to handle the great increase in calls. The number of attempted calls from residents therefore would have been larger than the counted calls indicate. The total number of telephone circuits in the damaged area was 517,000 the number in Kita and Nishi Wards being excluded due to the little damage done there. At the time of the earthquake, 122,000 telephone circuits were disrupted. The total number of ambulances available at Kobe fire department was 15. These ambulances carried about 400 injured people daily to hospitals, the maximum carrying capacity of the ambulances.

3. FIRE FIGHTING

The total number of fires was 176, and the number of houses and buildings burned down was 7,453. The area devastated by a fire was one million square meters. Nagata Ward had many chemical shoe companies, most of which were small or tiny enterprises occupying narrow areas. Some of their chemical products contributed to enlargement of the fires. Fortunately, on January 17th and 18th, there was no or very little wind. The Hanshin Expressway and JR-West Railway played important roles as firebreak zones. Fire engines and crews that came from other cities and towns, encountered some problems: traffic jams in damaged areas delayed early arrival, many of the fire hydrants and the water supply systems were broken, collapsed houses and buildings covered the roads and stopped traffic, and ambulances from nearby cities and towns could not come to the damaged areas due to the lack of working arrangements among local governments. Consequently the increasing firefighters was piecemeal (Fig 4). On January 17th, 800 firemen arrived and on the 20th (after 4 days) 2,400 were present. Such a gradual increase was not good for the early attempts at fire fighting.

The reason why so many fires broke out during the early morning is not clear. Osaka Gas Company supplies city gas (LNG) to this area, and about 70% of the residences were equipped with gas meters which would automatically stop the gas flow at the time of an earthquake. Less than 10% of the residences, however, were using gas at the time, therefore, these devices only partly contributed to reducing the occurrence of fire. At 5:46, on January 17, the streets were very dark without streetlights, and it was difficult to move or act due to electric power failure. To rescue victims under the collapsed houses, some neighbors used matches and lighters which may have caused fires due to gas leaks at broken pipelines with low pressure. There was quick restoration of electric power by Kansai Electric Company, which also may have generated fires owing to short circuits or overheated heaters. For example, the heaters of broken water

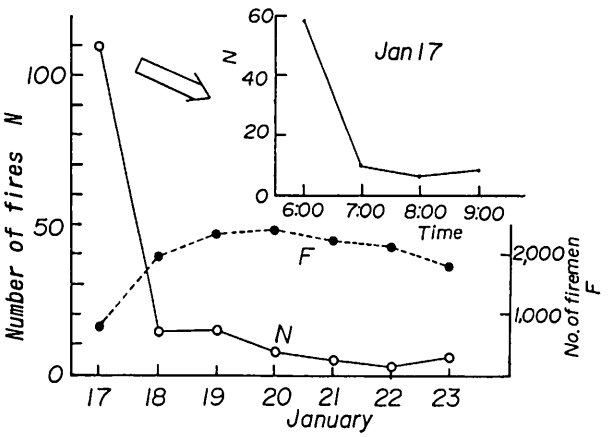

Fig. 4. Numbers of fires and firefighters.

tanks in which tropical fishes were kept was on cause of fire. The switching on of electric appliances by fallen furniture or collapsed houses also was a main cause.

For a long period, the Kobe City fire department has tried to decrease the number of fires. Firemen usually visit companies and private houses and give guidance for fire prevention. Fortunately, the number of fires has gradually decreased, but the numbers of fire engines and firemen also have decreased. This is general trend in Japan. At the time of catastrophic disaster, however, the simultaneous outburst of fires at many places can not be handled by such a system.

4. LIFELINE DAMAGE

The Hanshin area is located between the Rokko Mountains (highest peak 931m) on the north and the Seto Inland Sea on the south. This densely urban area stretches east and west, and average width being about 3km. In this narrow area, there are two national highways (Routes 2 and 43), an elevated highway (the Hanshin Expressway), three railways (the JR-West, Hankyu, and Hanshin). These were disrupted in many places except for Route 2. Other forms of mass transit; two subway lines, two monorails serving the Port and Rokko islands and two local railways also were disrupted due to collapsed tunnels, piers, and bridges. The Sanyo Shinkansen railway also was heavily damaged (elevated RC girders were broken at eight places and inside the Rokko tunnel the concrete lining was partially stripped off). The JR-West reopened on 1 April and the Sanyo Shinkansen on 10 April. The Hankyu and Hanshin railways respectively were restored to operation on 12 and 26 June. The repair processes for the area's lifelines are shown in Fig. 5. Damage and recovery of other lifelines were as follows:

1) Gas: High pressure pipelines suffered no damage and middle pressure lines were repaired

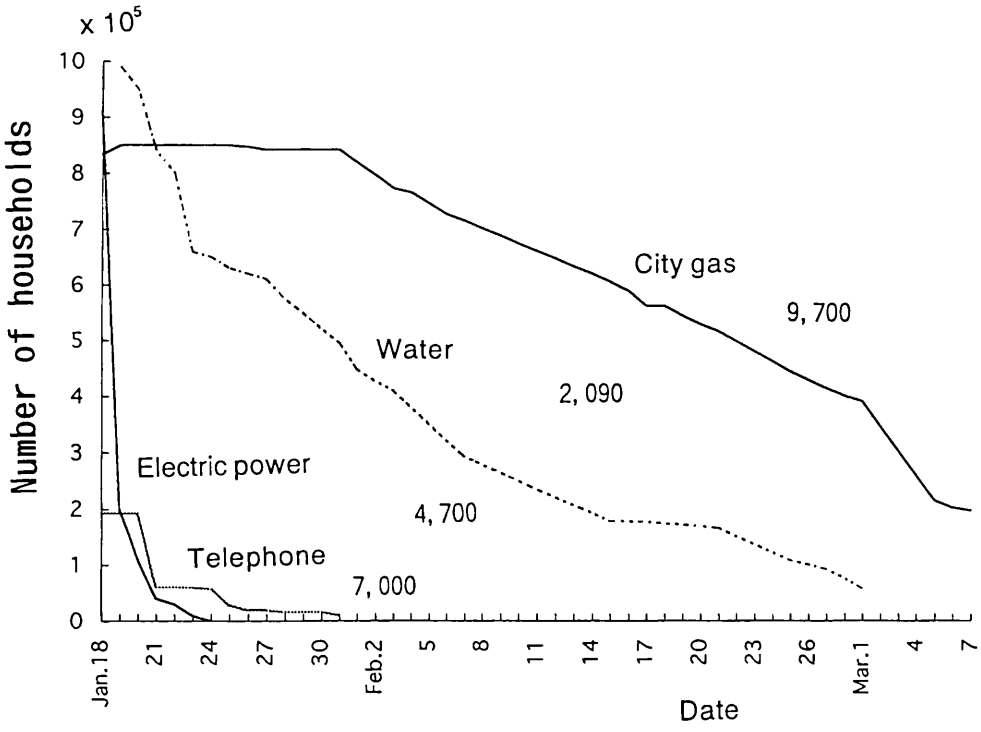

Fig. 5. Recovery of lifelines and the numbers of engineers engaged in repair work.

by January 31, whereas low pressure lines were completely destroyed. On January 17, the gas supply was cut off to 857,000 residences and on February 17 only 295,000 residences had the use of gas. By late March, the figure had increased to more than 98%. Slow recovery mainly was due to having to check each house and the intrusion of water that leaked from high pressure water supply pipelines into the broken gas pipelines. When gas cocks were turned on, water instead of gas was supplied to many residences. Some 9,700 engineers were engaged in gas line repairs .

2) Electric power: About 916,000 residences were blacked out but on January 23 only 2,000 residences were still without electricity. After the earthquake, 4,700 electrical engineers worked on repairs and the restoration of power. In Japan, electric power usually is supplied by wires strung from poles. In the case of collapsed houses and buildings, it was not necessary to supply electric power quickly so the engineers cut many useless electric wires. This is one of reasons for the quick restoration of electrical power.

3) Telephones: On January 17, about 285,000 telephone circuits were out of order. Until January 20, about 4,000 telephone linemen were engaged in restoration work, after that about 7,000 NTT employees were active in repair work. On January 31, restoration of service was complete, except for the 38,000 residences that had completely collapsed.

4) Water supply: The water supply was cut off to 1,355,600 cubic meters. The average daily supply rate was 1,363,000 cubic meters, 13% of the water coming from underground. A total of 2,090 public and private water company engineers cooperated in this restoration work. The length of pipeline worked on was 7,685km, of which 3,921km was in Kobe City. The total number of damaged points were 5,287 or 0.069 per km. As it was very difficult to find the points at which leakage of water occurred, a trial supply of water had to be used for each test. In Kobe City, fail safe systems for the main pipelines were present, but branch pipelines were severely damaged.

5) Waste-water: Kobe City has 43 water treatment plants, one sludge center, 3,315km of waste water pipes, and 484km of rainwater pipes. Due to the earthquake, 1,147 places in the waste water pipes and 267 places in the rain water pipes were damaged. Typical types of damage were the rising, sinking, and position gaps of 810 manholes. The pipeline points damaged numbered only 133.

5. BUILDING DAMAGE

Fully collapsed and half ruined houses in Hyogo Prefecture respectively totaled 92,877 and 99,829 (as of April 24, 1995). Although many construction companies helped check the damage

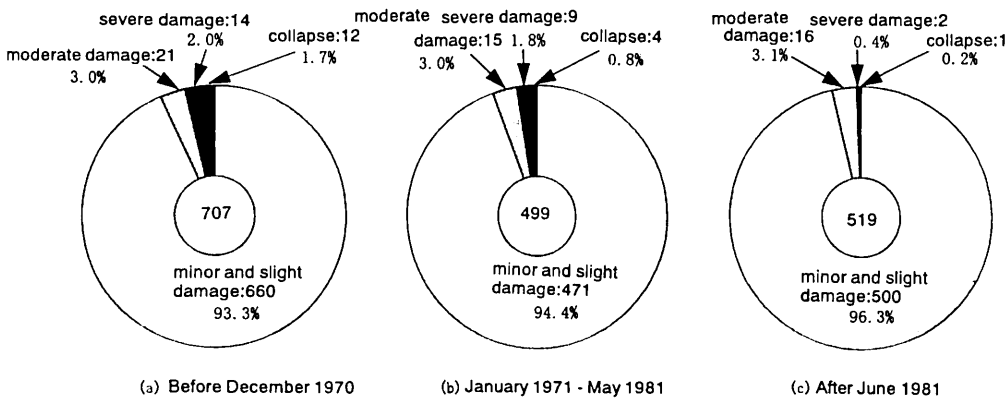

Fig. 6. Damage to buildings by period of construction.

Table 2. Building damage.

structural type	collapse or severe damage	moderate damage	minor or slicht damage	Total
RC/SRC	610	347	1,797	2,754
Steel	457	348	971	1,776
Total	1,067	695	2,768	4,530

done to RC and SRC buildings, none of the private building data have been collated, therefore accurate assessment of damage enlargement is not yet known. After the 1978 Miyagiken-Oki earthquake disaster, new seismic building and structure codes were enacted. Buildings erected in accordance with the new code suffered little damage, whereas damage to older ones was severe. The downtown Sannomiya area had many old concrete buildings that included Kobe City Hall, Kobe West Civic Hospital, the Daimaru and Sogo department stores, and the Hyogo Police Station. Many of these public buildings were severely damaged. This is one reason why the official response to the earthquake was late. Fig. 6 shows the percentages of collapsed buildings which had been constructed by the Takenaka Construction company [1].

On the basis of the preliminary reconnaissance report, Table 2 shows damage statistics as a result of the survey [2]. Damage is defined as follows:

1) Collapse: Failure or overturning of the entire structure or the complete failure of a single story.

2) Severe damage: A large portion of the building frame is damaged. Permanent deformation of the structure may cause imminent collapse.

3) Moderate damage: Significant structural damage is visible. Permanent deformation between stories exists, but there is low probability of collapse.

4) Minor damage: Minor structural damage, although the structure may have significant architectural damage.

5) Slight damage: No structural damage. Architectural damage may be noticeable.

The number of buildings in the collapsed and severely damaged categories exceeds 1,000. Buildings that suffered at least moderate damage exceeded 1,760.

6. SHELTER

After the earthquake, more than 300,000 people took refuge in schools, city halls, community centers and other public buildings, private tents in parks, school play grounds, and open spaces along roads. On January 23 and 24, the maximum number of refugees was recorded, 316,678, of which 235,443 were in 601 shelters in Kobe City. Changes in the numbers of shelters and refugees in Kobe City with time are shown in Fig. 7. In mid-April, more than 40,000 people were living in shelters because construction of temporary housing had not gone smoothly. In most damaged areas, there was little public open space. Space for construction was available only on inconvenient reclaimed land or in rural areas. People wanted to live in a temporary housing area with neighbors who lived in the same areas before the disaster, whereas housing selection was independent of this condition. Moreover, older people needed helpers and volunteers, and at the shelters, such assistance was readily available. The volunteers totaled more than one million, and they came from all over Japan, the first such massive volunteer action seen in Japan. Many university

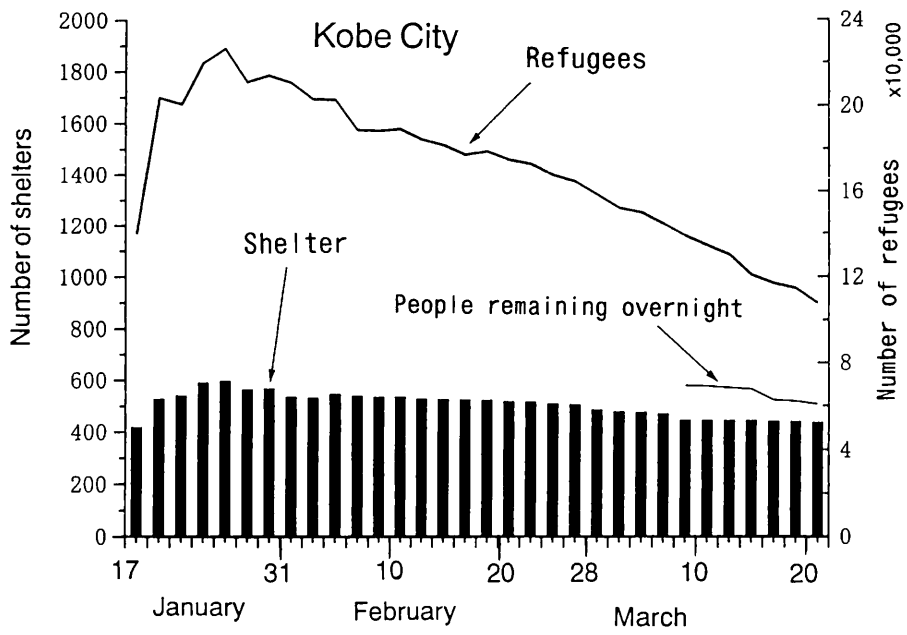

Fig. 7. Numbers of refugees and shelters.

students gathered in the damaged areas. As the Japanese Red Cross does not systematically organize such volunteers, their training and registration were became important, even urgent problems.

7. ECONOMIC IMPACT

Loss of capital stock was estimated to be about ¥11.6 trillion ($136.4 billion, exchange rate: $1 = ¥85) [3]: public infrastructures, ¥3.1 trillion; production facilities and property, ¥3 trillion; private houses and buildings, including property and furniture, ¥3.6 trillion. (Table 3). The Japanese GDP is ¥466 trillion, giving a damage rate of 2.5%.

Direct property damage totals were

Electric power: ¥230 billion ($2.7 billion)
Gas: ¥190 trillion ($2.2 billion)
Telephone: ¥90 billion ($1.1 billion)
Railway: ¥291 billion ($3.4 billion)
Steel companies: ¥74 billion ($0.87 billion)
Distribution (department stores and super markets) ¥152 billion ($1.79 billion)

Kobe City has been the home of such traditional industries as the manufacture of synthetic shoes, Japanese sake, and apparel and fashion design. In the case of the synthetic shoes factories, more than 1,600 manufacturers and their affiliates were clustered in Nagata Ward, one of the city's most densely populated areas. At more than 80 billion yen annual output, it was one of Kobe's largest industries. Nearly 90% of these business were destroyed by the earthquake and subsequent fires, and the damage suffered was estimated at a minimum of ¥350 billion. The 1,600 manufacturers located there accounted for about 80% of the country's factories and more than 70% of the shipments made nationwide. Moreover, most of the workers in these shoe companies lived in and around Nagata Ward, and most did not show up for work for some time after the earthquake, as they were busy taking care of their families and property.

Table 3. Estimated property damage.

Total of property damage	¥11,6 trillion
Public infrastructure	3.1
roads, railroads	1.2
ports	1.4
electric power, gas, water, telephone	0.5
Enterprises	3.0
facilities	0.5
structures	2.5
Private	3.6
houses	2.6
furniture	1.0
Miscellaneous	1.9

In eastern Kobe and in Nishinomiya City, there are large Japanese sake industries which have histories of more than 300 years of production. Along the south foot of the Rokko Mountains, at Nada, there is good quality underground water for making sake. The fifty breweries' products make up about one-third of the country's output. All of the traditional wooden sake factories collapsed, and some RC buildings suffered severe damage. Sake brewing in the area usually is in full swing between November and March, the cold temperature months in which sake is made, so large amounts of stock were lost.

Commerce statistics for Kobe City sets the sales total for fashion industry items such as clothes, apparel, and accessories including pearls at ¥793 billion. The total industrial output was ¥6,586 billion at wholesale prices, of which fashion sales accounted for 12%. Fortunately, the designing, planning, and delivery sections were located within the city and the manufacturing plants scattered on the outskirts, therefore the main damage done was to computer networking.

Heavy industries such as steel, shipbuilding, and mechanical facilities that were located along the coast were all severely damaged. Before the earthquake there a shift from heavy industry to information-communication, which type of industry now is being more actively promoted.

8. KOBE PORT

Kobe has a 130-year tradition as an international port, and ranks as the sixth largest cargo port in the world. It handled about 40 million tons of international container cargo (about 2.5 million containers) in 1993, and has been the country's largest container port (its share was 30%). Damage to the port facilities included the severe collapse of 239 berths, of which 35 container births collapsed due to liquefaction, and the members of the tall gantry cranes used to load containers buckled due to intensive ground motion. All the container berths with a depth of 12m on Port Island and those with a depth of 14m on Rokko Island were broken due to liquefaction and strong earthquake motion. The estimated cost of the damage was 1.4 trillion yen. Maritime transport companies have since switched to such other domestic ports as Osaka and Yokohama and to foreign container ports such as Hong Kong and Pusan. If a new route

for cargo distribution is established, attracting customers back to the old Kobe route will be difficult. By the end of April 1995, six container berths had been reopened, and one-third of the berths repaired. Before 1997, the other damaged berths will be usable.

9. PSYCHOLOGICAL CARE

The earthquake created enormous psychological stress for the more than 2.4 million survivors living in the damaged areas. It was the first instance of extended humanware management in our country (humanware means items related to human activities). Traditionally, Japanese people have shown much patience against such emotional stress known as "*gaman zuyoi*" In the damaged areas, little looting or disorder was reported even under continuing miserable conditions. Systematic psychological stress care exercised for the earthquake victims was as follows:

1) Information was disseminated about post traumatic stress disorder (PTSD) in various kinds of brochures as well as in the mass media.

2) Outreach counseling was given the earthquake homeless living in shelters. In earthquake disasters, school children experience severe mental stress so that counseling for them is very important. Professional counselors and trained volunteers have been working with these survivors, and counseling will continue for more than two years.

10. RECOVERY

Guidelines for the recovery of Kobe City were issued in late March 1995. They were proposed by the committee for recovery planning. Actual plans were issued in late June 1995 by a recovery council. The guidelines cover the next 10 years, the final goal of total urban construction being 2005. In Kobe City, six severely damaged areas were designated according to building code 84, under which law construction of only one- or two-story wooden houses will be permitted. The principle for restoration is to separate the center of the city into a number of local centers connected by networks for traffic and other types of communications and culture centers. In this process, it has been promised that the opinion of residents will be reflected in the final plans.

11. LESSONS

There are many important lessons to be learned from this earthquake disaster:

1) Reinforcement of old buildings and infrastructures: As Japan has experienced many earthquake disasters, the seismic code has been revised The Great Hanshin-Awaji disaster showed that buildings and infrastructures designed under the new code issued in 1981 are mostly safe. During the 1970s the economy developed and public investment was seen in the construction of the Shinkansen railroad, the Meishin Expressway and urban elevated highways as well as downtown high rise office building in big cities. The 1968 Tokachi-Oki and the 1978 Miyagiken-Oki earthquake disasters struck subsequent to changes in the seismic building code, but construction management was not very specific and systematic at that time.

2) Revision of the Disaster Countermeasure Act: This act became law in 1961, after the Ise Bay typhoon in which 5,101 people were killed. At that time, our country was very poor so that the restoration of the original form of the infrastractures before the disaster was the fundamental government policy. Disaster investment in response to changes in the disaster characteristics that accompany changes in the social environment has had no financial support from the government. Fortunately, there were no major disasters in the big cities for more than 30 years. During these years, there has been large scale urbanization, and many people have moved to cities from rural districts. Disaster investment, however, has not been proportional to the increase in the urban population. As Kobe has not experienced a strong earthquake for more than 1,000 years, its

regional disaster planning did not include provisions for such a far-reaching disaster. The most important characteristic of urban disasters is that the scenarios of human damage enlargement can not be known in advance.

3) Expensive land costs have stopped public works projects within the inner city: During the bubble economy of the late 1980s through early 1990s, land costs increased sharply year by year. Every bank lent much money to businesses, land owners, and individuals. During that time, it was very difficult to buy land for infrastructure construction or the redevelopment of urban area. No redundancy or fail-safe systems were adopted. The expansion of urban areas was too large. The total balance of urban activity and life have never discussed macroscopically. The socially weak, such as the old, poor people, and the physically handicapped, were left alone inside the inner city to inhabit old, jerry-built wooden houses densely distributed and surrounded by narrow streets, many small factories and residential houses being located together.

4) Disaster reduction or mitigation must be adopted: In Japan, no level of government has been accustomed to provide disaster management. Traditionally, importance has been put on risk management before disasters, but crisis management after a disaster is equally important. For example, the logistics of providing materials, workers, and communications just after a disaster is extremely important, but in Kobe City there was no food, water, or blankets stockpiled, nor were there any in all of Hyogo Prefecture. I propose that reconstruction plans have to be prepared before a disaster occurs, because it takes a very long time and because accurate damage estimation before a disaster is very important for rescue and recovery efforts.

5) Disaster management should be based on philosophy: To have a good urban environment, social mitigation is very important. Social mitigation means the restoration of the urban environment lost due to Japan's rapid industrialization during the1970s and 1980s. Previously public works had been kept in balance with such urban functions as economics and life style, but during the 1990s the total urban system has not been in good balance with urban life. The engineering and technical aspects of disaster measures are often discussed without taking into account the holistic and social significance of disaster-related subjects. Without a clear understanding of how a society values safety and assurance, it will be impossible to obtain a good urban environment. The philosophy of disaster management therefore is very important.

6) Management of information is the key to disaster reduction: In catastrophic disasters, both the natural (physical processes of the generation and enlargement of damage) and the social (search and rescue, psychological care for post traumatic stress disorder, volunteers) factors are important. Information systems should be able to co-ordinate them at the time of a disaster. As yet there are no practical GIS (Geographical Information Systems), but the development of such systems will help reduce human and property damage.

12. CONCLUSIONS

In the afternoon of January 17, 1995, I visited Higashinada Ward. The area looked like a ghost town, as its people had gone to shelters in fear of aftershocks. I will never forget the scene of the collapsed houses, buildings, highways, and container berths. I visited Kobe more than 30 times during the first three months after the disaster. Before the earthquake, the population of Kobe City was about 1.47 million, this decreased to less than 1.3 million. More than 20,000 people were still in shelters in late June, most of them old and/or without money to repair or rebuild their homes. The aged survivors suffer from chronic complaints of aging and traumatic stress disorder caused by the earthquake. They need extensive help from the local, prefectural and national governments and from volunteers. All our energies now must be concentrated on the recovery process.

In preparing this paper, I have referred to many newspaper articles, preliminary technical

reports, and interviews with survivors of the earthquake and with local government officers. After two to three years we should have a complete analysis of this disaster, based on the field surveys done by various academic societies. The objectives of my research, however, was not to analyze the disaster but to consider the prevention and mitigation of natural disasters.

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